

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

**APPLICATION FOR UNITED STATES LETTERS PATENT**

**TITLE:** GATE VALVE WITH FLOW-THROUGH GATE

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## Gate Valve with Flow-Through Gate

This application is based on U. S. Provisional Patent Application No. 60/192,124, which was filed on March 24, 2000.

### Background of the Invention

5           The present invention relates to a gate valve which may be used to remotely control the flow of fluid through various components of a flow completion system, such as a tubing hanger. More particularly, the invention relates to such a gate valve which comprises a flow-through gate and which therefore occupies a minimum of the radial cross sectional area of the  
10   component.

          The need to remotely and reliably control the flow of fluid through components having relatively small radial cross sectional areas is particularly strong in the field of flow completion systems for producing oil or gas from a subsea well. For example, a typical flow completion system comprises a tubing  
15   hanger which is suspended in a wellhead housing or a tubing spool and which supports at least one tubing string that extends to the well bore. The tubing hanger includes at least one axial production bore through which the well fluids are produced, one or more service and control conduits for communicating control signals or fluids from external service and control lines to corresponding  
20   devices or positions located in or below the tubing hanger, and possibly also a longitudinal annulus bore for connecting the tubing annulus with the portion of the flow completion system that is located above the tubing hanger.

In operation of the flow completion system, flow through the annulus bore and the service and control conduits must be carefully controlled to ensure that the well fluid does not escape into the environment. However, in view of the several bores that extend through the tubing hanger, little radial cross sectional

5 area is available for installing a standard closure member, such as a gate valve. Moreover, in the prior art a wireline plug is typically used to close the annulus bore. However, each installation or removal of the plug requires a special running trip from a surface vessel. Furthermore, although several versions of remotely operable valves for controlling flow through the tubing hanger bores

10 have been patented, these valves have for the most part been impractical to implement due to the limited radial cross sectional area that is available in the tubing hanger for such valves.

Therefore, a need exists for a remotely operable valve which can reliably control the flow of fluid through a flow completion system component but which

15 occupies a minimum radial cross sectional area of the component.

#### Summary of the Invention

In accordance with the present invention, these and other disadvantages in the prior art are overcome by providing a gate valve for controlling the flow of fluid through a flow completion system component having a fluid flow passage

20 that includes at least a first branch and a second branch. The gate valve comprises a gate cavity which communicates with both the first branch and the second branch, a gate which is movably positioned in the gate cavity and which includes a first flow port that is connected to a second flow port, and an actuating

mechanism for moving the gate between an open position, in which the first flow port is aligned with the first branch and the second flow port is in communication with the second branch, and a closed position, in which the first flow port is offset from the first branch, wherein the second flow port is divergent from the first flow port. In this manner, when the gate is in the open position the direction of the flow of fluid through the gate valve is changed by the first and second flow ports. In one embodiment of the invention, the second flow port is approximately perpendicular to the first flow port. In another embodiment of the invention, the gate comprises a third flow port which is approximately perpendicular to the second flow port and which is aligned with the second branch when the gate is in the open position.

Therefore it may be seen that the gate valve of the present invention provides a reliable yet compact device for remotely controlling fluid flow through the flow completion system component. The gate valve is similar to a conventional gate valve, which is recognized as being a robust and reliable closure member. In addition, the actuating mechanism permits the gate valve to be operated remotely, which therefore eliminates the need for separate running trips from a surface vessel to open or close the gate. Furthermore, since the direction of the fluid flow is changed through the gate, the first and second flow passages may be oriented generally axially and the lateral dimension of the gate cavity can be reduced so as to occupy a minimum radial cross-sectional area of the flow completion system component.

These and other objects and advantages of the present invention will be made apparent from the following detailed description, with reference to the accompanying drawings. In the drawings, the same reference numbers are used to denote similar components in the various embodiments.

## 5 Brief Description of the Drawings

Figure 1 is a longitudinal cross-sectional view of an exemplary flow completion system in which the gate valve of the present invention is installed;

Figure 2 is a longitudinal cross-sectional view of the tubing hanger component of the flow completion system of Figure 1 showing the gate valve of  
10 the present invention installed therein;

Figure 3A is a longitudinal cross-sectional view of the gate valve of Figure 2 shown in the closed position;

Figure 3B is a longitudinal cross-sectional view of the gate valve of Figure 2 shown in the open position;

15 Figure 3C are radial cross-sectional views of three alternative gate components of the gate valve shown in Figure 2; and

Figure 4 is a longitudinal cross-sectional view of another embodiment of the gate valve of the present invention.

## Detailed Description of the Preferred Embodiments

20 While the gate valve of the present invention may be used to control flow through a variety of flow completion system components, it will be described hereafter in connection with the tubing hanger component of an exemplary flow completion system.

Referring to Figure 1, a preferred embodiment of the gate valve 10 is shown installed in an exemplary flow completion system 12. As explained more fully in applicants' co-pending U.S. Patent Application No. [FMC Docket No. 66-12272], which is hereby incorporated herein by reference, the flow completion

5 system 12 comprises a wellhead housing 14 which is installed near the top of a well bore (not shown), a tubing spool 16 which is connected over the wellhead housing 14 and which includes a central bore 18 that extends axially therethrough, and a tubing hanger 20 which is supported in the central bore 18 and which includes a generally annular body 22 having an outer, stepped

10 cylindrical wall 24. The tubing hanger 20 supports at least one tubing string 26 which extends into the well bore and defines a tubing annulus 28 surrounding the tubing string. In addition, the tubing hanger 20 includes a concentric production bore 30 which communicates with the tubing string 26, a lateral production passageway 32 which extends between the production bore 30 and a production

15 outlet 34 in the tubing spool 16, an annulus bore 36 which extends generally axially between the tubing annulus 28 and a portion of the central bore 18 located above the tubing hanger, and a number of service and control conduits 38 which extend generally axially through the tubing hanger. The flow completion system may also comprise one or more valves 40 for controlling flow

20 through the production outlet 34, and a controls bridge 42 for connecting the annulus bore 36 and the service and control conduits 38 with corresponding external service and control lines (not shown).

In the flow completion system 12 depicted in Figure 1, the tubing hanger 20 preferably also includes both of the industry required first and second barriers between the well bore and the environment, thus eliminating the need for a separate pressure sealing tree cap. The first barrier is provided by a first wireline crown plug 44 that is disposed in the production bore 30 above the production passageway 32, and a first annular, preferably metal seal 46 which is positioned between the tubing hanger 20 and the tubing spool 16 above the production passageway. Similarly, the second barrier is provided by a second wireline crown plug 48 that is mounted in the production bore 30 above the first crown plug 44, and a second annular, preferably metal seal 50 which is positioned between the tubing hanger 20 and the tubing spool 16 above the first seal 46. In accordance with the present invention, the tubing hanger 20 also includes the gate valve 10 and, in the embodiment of the invention depicted in Figure 1, preferably also a second closure member 52, such as a sting open check valve, for controlling fluid flow through the annulus bore 36.

Referring to Figure 2, substantially all of the operational components of the gate valve are housed entirely within the body 22 of the tubing hanger 20. In addition, the gate valve 10 is oriented generally axially within the body so as to occupy a minimum of the radial cross sectional area of the tubing hanger. In order to most readily accommodate this vertical orientation of the gate valve 10, the annulus bore 36 preferably includes a lateral branch which is connected to a longitudinal branch, and the gate valve is disposed within a gate cavity that is positioned between the branches. For example, in the embodiment of the

invention depicted in Figure 2, the annulus bore 36 is shown to comprise a first branch 54 which extends generally laterally through the body 22, a second branch 56 which extends generally axially through the body between the first branch and the tubing annulus, a third branch which extends generally laterally through the body, and a fourth branch which extends generally axially through the body between the third branch and the portion of the central bore 18 that is located above the tubing hanger.

Referring to Figure 3A, the gate valve 10 is shown to comprise a gate cavity 62 which is formed in the body 22 of the tubing hanger 20 and is connected to the first and third branches 54, 58, two preferably floating seats 64, each of which is mounted in a respective seat pocket 66 that is formed in the body at the intersection of each branch 54, 58 with the gate cavity, a gate 68 which is slidably disposed within the gate cavity adjacent the seats, and an actuating mechanism 70 which is positioned in a service and control conduit 38 that is oriented generally vertically over the gate cavity. The gate 68 includes a generally flat face 72 which is adapted to sealingly engage the seats 64 when the gate valve 10 is in the closed position. In addition, the gate 68 may have any of a variety of transverse cross-sectional configurations, including any of the configurations depicted in Figure 3C.

The gate 68 also comprises a generally lateral first flow port 74 which extends from the face 72, a generally longitudinal second flow port 76 which is connected to the first flow port, and, in the embodiment of the invention depicted in Figure 3A, a generally lateral third flow port which extends between the second



flow port and the face 72. Thus, the second flow port 76 is divergent from the first flow port 74, and the third flow port 78 is divergent from the second flow port 76. In the context of the present invention, this means that the axis of the second flow port 76 is offset angularly relative to the axis of the first flow port 74, and the axis of the third flow port 78 is offset angularly relative to the axis of the second flow port 76. In the embodiment of the invention shown in Figure 3A the amount of angular offset between both the second and first flow ports and the third and second flow ports is approximately ninety degrees. In this manner, the flow ports function to change the direction of fluid flow through the gate 68 by 180 degrees.

The actuating mechanism 70 functions to move the gate 68 between a valve open position, in which the first flow port 74 is aligned with the first branch 54 and the third flow port 78 is aligned with the third branch 58, and a valve closed position, in which the first and third flow ports 74, 78 are offset from the respective first and third branches 54, 58. In the embodiment of the invention depicted in Figure 2, the actuating mechanism 70 is similar to that described in applicants' co-pending U.S. Patent Application No. [66-12273], which is hereby incorporated herein by reference. Thus, the actuating mechanism 70 comprises a piston head 80 which sealingly engages the service and control conduit 38, a valve stem 82 which is connected between the piston head and the gate 68, and a mechanical return biasing mechanism 84, such as a stack of Belleville washers, that is operatively engaged between the piston head 80 the body 22 of the tubing hanger 20.

In the embodiment of the invention shown in Figure 3A, the actuating mechanism 70 includes a piston 86 which sealingly engages the service and control conduit 38 and which is connected to the gate 68. The actuating mechanism 70 also comprises a mechanical return biasing mechanism, such as a spring 88, which is operatively engaged between the gate 68 and the body 22 to urge the gate into, for example, the closed position. The spring 88 may be positioned between the bottom of the gate 68 and the bottom of the gate cavity 62, in which event the actuating mechanism 70 preferably also includes a stop sleeve 90 to limit the downward movement of the gate 68. Of course, actuating mechanism, including the return biasing mechanism, could be any mechanical, electrical or hydraulic mechanism that is currently known by those skilled in the art to be useful for moving the gate between its open and closed positions.

In the embodiment of the invention illustrated in Figure 2, the gate cavity 62 extends into the body 22 of the tubing hanger 20 between the first and second annular seals 46, 50 and consequently forms an opening 92 in the wall 24 that is positioned between the seals. The opening 92 is optimally closed by a simple cover plate 94 that may be secured to the tubing hanger 20 by any suitable means. The pressure within the gate cavity 62 is preferably contained by the first and second seals 46, 50 and a stem packing 96. Therefore, no need exists for a separate seal or seals between the cover plate 94 and the body 22 to contain the pressure within the gate cavity 62. However, the present invention contemplates that one or more such seals could be provided between the cover plate and the

body to contain the pressure within the gate cavity, especially when the opening 92 is not located between the seals 46, 50.

In the closed position of the gate valve 10, which is shown in Figure 3A, the gate 68 will seal off the annulus bore 36 by preventing fluid flow between the lateral first branch 54 and the lateral second branch 56. In order to ensure that the gate 68 sealingly engages the seats 64, the gate valve 10 may include a load reaction disc 98 which is threadedly received in a corresponding orifice in the cover plate 94. Accordingly, the load reaction disc 98 may be tightened against the gate 68 to ensure that it engages the seats 64 with sufficient force to prevent fluid from leaking past the seat-to-gate interface.

When it is desired to open the gate valve, pressurized hydraulic fluid is introduced into the service and control conduit 38 above the piston 86 through, for example, a male coupling 100. The hydraulic fluid will force the piston 86 downward, and the piston will in turn push the gate 68 downward until the gate contacts the stop sleeve 90. In this position, which is shown in Figure 3B, the lateral first and third flow ports 74, 78 are aligned with the lateral first and third branches 54, 56, respectively, and the annulus bore 36 is therefore opened. In order to return the gate valve to the closed position, the hydraulic fluid is removed from above the piston 86, thus allowing the spring 88 to push the gate 68 upward until it contacts the top of the gate cavity 62.

Referring now to Figure 4, another embodiment of a gate valve of the present invention, which is indicated generally at 110, is shown installed in a tubing hanger 20. In this embodiment, the annulus bore 36 of the tubing hanger

20 includes a first branch 112 which extends generally laterally through the body 22 from the gate cavity 62, a second branch 114 which extends generally axially through the body between the first branch and the tubing annulus, and a third branch 116 which extends generally axially through the body between the gate cavity and the portion of the central bore 18 that is located above the tubing hanger. In addition, the gate valve 110 of this embodiment comprises a single seat 64 which is mounted in a seat pocket 66 that is formed at the intersection of the lateral first branch 112 with the gate cavity 62, and a gate 118 which is slidably disposed in the gate cavity 62 against the seat 64. The gate 118 includes a front face 120 which sealingly engages the seat 64, a generally lateral first flow port 122 which extends from the front face, and a generally longitudinal second flow port 124 which extends between the first flow port and the top of the gate. In this manner, the gate will change the direction of the fluid flow by 90 degrees.

The gate valve 110 also comprises an actuating mechanism 126 for moving the gate 118 between an open position, in which the lateral first flow port 122 is aligned with the lateral first branch 112, and a closed position, in which the first flow port is offset from the first branch. The actuating mechanism 126 includes a piston 86 which sealingly engages a bore 128 that is positioned below the gate 118, a conduit 130 for connecting the bore with a source of negative pressure, and a return biasing mechanism, such as a spring 88. Of course, the actuating mechanism 126, including the return biasing mechanism, can be any

such mechanism disclosed herein or in applicants' above-mentioned co-pending U.S. Patent Application No. [FMC Docket No. 66-12273].

When the gate valve 110 is in the closed position, which is shown in Figure 4, the gate 118 will seal against the seat 64 and prevent fluid from flowing  
 5 between the first and third branches 112, 116 of the annulus bore 36. As in the previous embodiment, the gate valve 110 preferably includes a load reaction disc 98 for urging the gate 118 into tight sealing engagement with the seat 64. In order to open the gate valve 110, the bore is exposed to the source of negative pressure via the conduit 130. The negative pressure will consequently draw the  
 10 piston 86, and thus the gate 118, downward into the open position. When it is desired to again close the gate valve 110, the negative pressure is removed from the bore 128, thus allowing the spring 88 to push the gate upward into the closed position.

It should be recognized that, while the present invention has been  
 15 described in relation to the preferred embodiments thereof, those skilled in the art may develop a wide variation of structural and operational details without departing from the principles of the invention. For example different features of the various embodiments may be combined in a manner not discussed herein. Therefore, the appended claims are to be construed to cover all equivalents  
 20 falling within the true scope and spirit of the invention.